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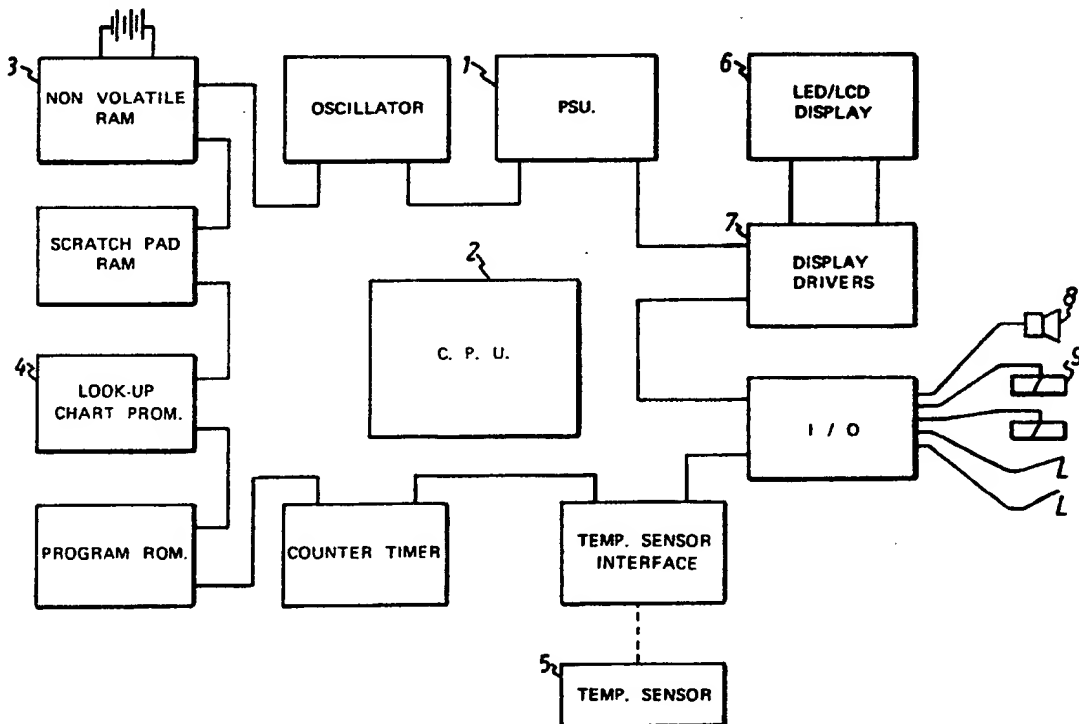
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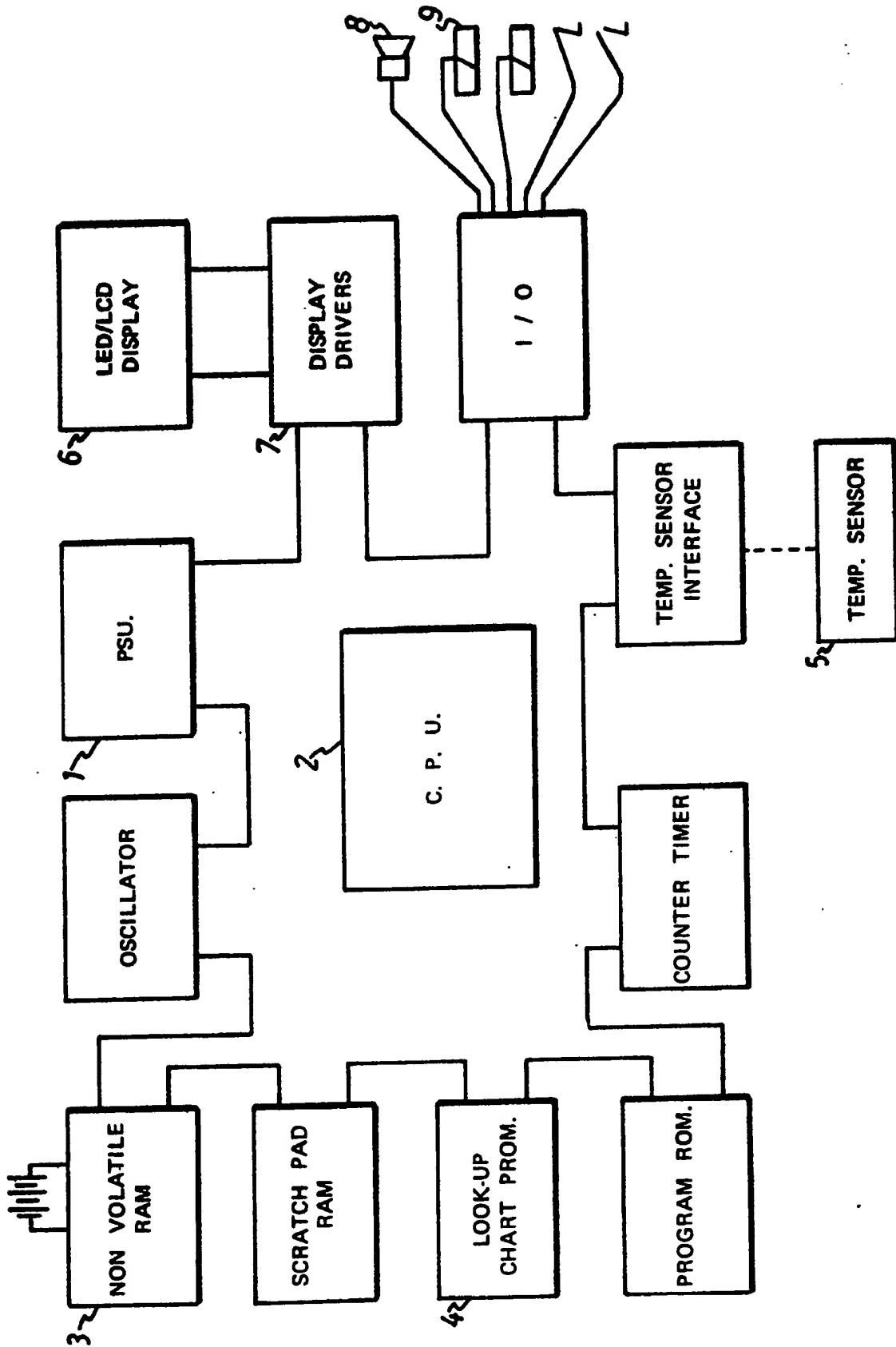
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(54) **Motor temperature monitoring system**

(57) A monitoring device for an electrical motor has means (5) for monitoring the temperature of a motor, memory means (4) containing predetermined operational data relating to the operating characteristics of the motor, control means (2) for correlating the sensed temperature with the predetermined operational data to provide an output representing the sensed temperature as a percentage of the operating temperature range, and means (6) for displaying the output. An audible alarm 7 is also provided, and the motor cuts out automatically if a preset temperature is exceeded. The cut-out may be overridden by an operator unless an absolute maximum temperature is reached.



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A MONITORING SYSTEM

The present invention relates to a monitoring system for electric motors and more particularly to a monitoring system which provides an indication of a motors useful operating capacity. The monitoring system also allows an historical record to be made of the motors operating conditions during its working life.

Temperature monitoring of large AC motors and DC servo motors is presently undertaken to ensure that the wiring inside the motor is not damaged as a result of overheating. Usually the monitoring device prevents further operation of the motor until such time as the temperature has dropped back to a safe operating level. It is usual to find temperature monitoring in motors which are particularly expensive to replace.

Low cost DC motors have traditionally been constructed as series-wound or shunt-wound motors and, in more recent times, as permanent magnet motors. Permanent magnet motors allow the speed of the motor to be varied using pulse width modulation (PWM) techniques. As a general rule low cost motors are not provided with any temperature monitoring facilities, although in some cases they may have simple thermal trips to switch them off in the event of over-heating.

Whilst temperature monitoring has been used to protect motors against being operated at unacceptably high temperature levels, conventional temperature monitoring systems do not provide any indication of the motors useful operating capacity under specific operating conditions. Since different thermal

capacity motors must be used to suit different operating conditions. this means that a motor may end up being used in a totally unsuitable application and no indication of this will be provided until the motor actually fails. In this respect, it will be appreciated that the motor may be continuously run up to its maximum permitted operating temperature, or just below, without the temperature monitoring system actually cutting-out and the working life of the motor is, as a consequence, much reduced.

It is an object of the present invention to provide a monitoring system for electrical motors which provides an indication of a motors useful operating capacity under any particular operating conditions.

It is a further object of the present invention to provide a monitoring system for electrical motors which enables an historical record to be made of the motors operating conditions during its working life.

According to a first aspect of the present invention there is provided a method of monitoring the operating capacity of an electric motor, wherein the temperature of a motor is sensed, the percentage value of the absolute maximum operating temperature of the motor represented by the sensed temperature is determined and the percentage value is indicated.

Conveniently, the percentage value of the absolute maximum operating temperature of the motor represented by the sensed temperature is determined by interpolating predetermined operational data, relating to the operating characteristics of the motor, with the sensed temperature.

Preferably, the motor cuts-out if its operating temperature exceeds a predetermined maximum permitted operating temperature and is prevented from operating again until the temperature drops back below this level or a motor cut-out  
5      override is activated by the operator. This ensures that the motor is not unwittingly operated beyond its safe working temperature. If this were done frequently the working life of the motor would be dramatically reduced. However, the motor cut-out override ensures that the motor can still be operated  
10     in circumstances, where, for example, safety considerations override the risk of damage to the motor.

Preferably, the motor cut-out override cannot be overridden if the operating temperature of the motor exceeds a predetermined absolute maximum operating temperature of the  
15     motor, ie 100% of the operating temperature range. At this temperature destruction of the motor could occur and so it is inappropriate to be able to override the safety protection afforded by the motor cut-out.

Preferably, data relating to the operating conditions  
20     of the motor during its working life are recorded or stored in a memory. This data may comprise:-

- 1) the total running time of the motor;
- 2) the total number of operations performed by the  
      motor;
- 25     3) the number of times the motor is operated beyond the maximum permitted operating temperature;
- 4) the number of times the motor is shut-down as a

result of reaching the absolute maximum permitted temperature; and,

- 5) the operating conditions prevailing during the last operation.

5           This information can be accessed from the memory by an operative provided with appropriate memory reading equipment and/or an appropriate access code.

          The historical information stored during the working life of the motor shows the amount of abuse, if any, to which  
10   the motor has been subjected. This can be especially useful to the manufacturer in determining whether warranties and conditions of use have been fully complied with and avoids the need to remove the motor for examination. This information is also useful in determining the appropriateness of the motor to  
15   the application for which it is being used, ie whether it is being under or overworked.

          According to a second aspect of the present invention there is provided a monitoring device for an electrical motor comprising temperature sensing means for monitoring the  
20   temperature of a motor, memory means containing predetermined operational data relating to the operating characteristics of the motor, control means for correlating the sensed temperature with said predetermined operational data to provide an output representing the sensed temperature as a percentage of the  
25   operating temperature range and means for displaying said output.

          Preferably said memory means comprises a read only memory, preprogrammed with the predetermined operational data

relating to the operating characteristics of the motor.

Preferably, the indicator means comprises a plurality of LEDs each of which represents an incremental increase in the percentage of the operating temperature range. Advantageously, the LEDs are different colours to represent different operating stages, e.g. green denotes a safe operating temperature, yellow is a warning and red indicates that a danger level has been reached. Alternatively, other indicator means such as a quartz crystal display or indicator lights may be used.

Preferably, the control means comprises a motor cut-out which interrupts the supply of power to the motor if its operating temperature exceeds a predetermined maximum permitted operating temperature and prevents it from operating again until the temperature drops back below this level. The control means also comprises a manually operated motor cut-out override whereby the supply of power to be to the motor to be recommenced by an operator.

Preferably, the control means comprises means whereby the motor cut-out override may be automatically overridden should the operating temperature of the motor exceed a predetermined absolute maximum operating temperature of the motor, ie 100% of the operating temperature range.

Preferably, the monitoring device comprises additional memory means for storing data relating to the operating conditions of the motor during its working life. This additional memory means takes the form of a random access memory into which data is input from the control means. In this respect the monitoring device conveniently comprises a timer

device which is turned on each time the motor is operated and switched off when the motors operation is concluded, the output being accumulated in the memory means through the control means. Additionally, the control means comprises counter means.

5           The control means itself preferably comprises a central processor unit.

Conveniently, the information stored in the additional memory means can be accessed by means of a data link. This data link may conveniently take the form of an infra red transmitter  
10   and an infra red sensor, although other forms of data link are equally applicable.

An embodiment of the present invention will now be described, by way of example, with reference to the accompanying drawing, which shows a block circuit diagram of  
15   a monitoring device in accordance with present invention.

Referring to the accompanying drawing there is shown a monitoring device in accordance with the present invention which essentially comprises a power supply 1, a central processor unit 2 (CPU), a non-volatile random access memory  
20   (RAM) 3, read only memory (ROM) 4, temperature sensor 5 and an indicator display 6. The temperature sensor 5 is intended, in use to be mounted inside a motor to be monitored and as such it is separate from the rest of the monitoring device. In practise it would be connected to the rest of the monitoring  
25   device by means of a cable and connector arrangement.

The indicator display 6 comprises a total of twenty light emitting diodes (not shown separately) each of which is separately driven by display driver unit 7. Conveniently, the

indicator display 6 divides the motors recommended working temperature range into sections, each of which is indicated by a respective LED of the LED indicator display. With twenty LEDs each one indicates an increase of 5% in the operating temperature of the motor. Conveniently, different coloured LEDs are used to denote the different temperature states of the motor. Green LEDs could denote acceptable temperature levels, yellow a warning level and red the critical temperature level. Also associated with the indicator display 6 is an audio alarm<sup>8</sup> which sounds each time the temperature of the motor rises enough to illuminate another LED in the indicator display 6.

The random access memory 3 is intended, in use, to hold details of the motors operating conditions during its working life and in this respect it is provided with data from the central processor unit 2. The information stored in RAM 3 may be accessed by an operator provided with an appropriate data link and in the embodiment of the present invention shown in the accompany drawings this takes the form of an infra-red data link 9, although other forms of data link are equally applicable.

The central processor unit 2 constitutes the heart of the monitoring device in as much as it is responsible for controlling each of the various operations which are carried out by the device. In this respect, the CPU controls the supply of data to the random access memory 3, the operation of a motor control (not shown) and it also makes the necessary calculations from which control signals to the display driver unit 7 are provided.

Operation of the monitoring device will now be described:-

Prior to use the monitoring device is provided with details of the operating characteristic of the or each motor with which it is intended to be used. These details include the maximum permitted operating temperature and the absolute maximum operating temperature of the motor (the differences between these two parameters will be explained hereinbelow) and optionally, amongst other things, the ideal position of the temperature sensor 5 within the motor. These details are held in the read only memory 4.

The temperature sensor 5 is mounted in the motor and is connected up to the rest of the monitor device by a connecting lead. The signal output from the sensor 5 is proportional to temperature of the motor, but the sensor 5 is an analogue device and it is therefore connected to a digital to analogue convertor (not shown) which converts the output signal of the sensor 5 into a digital signal capable of interpretation by the CPU 2. Making use of the information stored in ROM 4 the CPU 2 interpolates the actual sensed temperature of the motor into a percentage of the motors recommended working temperature range and indicates this figure to an operative through the indicator display 6 by illuminating the appropriate number of LEDs in the display 6.

Associated with the monitoring device is a motor control (not shown) which, through a series of switches (not shown), enables the operator to energise the motor. Under normal operating conditions, that is to say, when the

temperature of the motor lies well below the maximum permitted operating temperature and in the acceptable range indicated by the indicator display 6, the motor control will energise the motor. However, as the motor is operated over a period of time  
5 heat will build up and the signal output from the sensor 5 will change. This is indicated to the operative as more and more lights in the display 6 are light and the audio alarm 7 sounds.

Should the operator repeatedly switch the motor on again after it has completed each operation or allow it to  
10 operate under an abnormally high load the temperature of the motor will rise rapidly to the point where the yellow warning LEDs are illuminated. At this point the audio alarm 7 will begin to sound continuously. Should the temperature continue to rise to the point where it reaches 100% of the motors  
15 operating temperature range the central processor unit will instruct the motor control to switch off the motor, regardless of any attempt which is made by the operative to override this instruction. As will be readily appreciated, at 100% of its operating temperature range failure of the motor is likely to  
20 occur almost immediately.

In the event that the motor has been used previously at an operating temperature in excess of the permitted maximum determined by its manufacturer, usually in the yellow range as indicated by the indicator display 6, the CPU 2 will override  
25 the motor control and prevent it from energising the motor again. This is to prevent the motor from being unwittingly operated beyond its permitted maximum temperature range, which will, of course, substantially reduce its useful working life.

However, if the operator is determined to override the motor control override, it is possible to instruct the CPU 2 to ignore the fact that motor was previously operated beyond its permitted maximum temperature. This is of considerable importance where, for example, safety considerations outweigh the disadvantages of causing permanent harm to the motor.

It should be noted here that a distinction is drawn between the permitted maximum operating temperature laid down by the motors manufacturer and the absolute maximum operating temperature of the motor. At the former the motor can be operated, even though the working life of the motor may be reduced. At the later failure of the motor will be imminent. Hence the reason why the permitted maximum can be overridden, whilst the absolute maximum cannot.

In addition to controlling the operation of the motor and the interpolation of the temperature sensed by the sensor 5 into an output shown on the indicator display 6, the CPU 2 also ensures that data relating to the operating conditions of the motor are passed to the non-volatile RAM 3 for storage. The actual data stored may vary from circumstance to circumstance, but as a general rule the following information is likely to prove most useful:-

- a) the number of times the motor is operated;
- b) the total length of time for which it operated;
- c) the number of times the motor is operated beyond its permitted maximum operating temperature;
- d) the number of shut downs (operations at absolute maximum operating temperature); and.

e) the operating conditions during the last operation or cycle.

The total length of time for which a motor is operated is determined by a counter device which is switched on each time the motor is eneregised for the duration of the operation.

The information listed above can be accessed from the non-volatile RAM 3 using the data link 9 and read out onto a readable display.

The CPU 2 may also output information from the ROM 4 relating to the type of motor which should be used in the particular application in hand, where the temperature sensor should be fitted in the motor and the like for display to the operator. This additional information, being preprogrammed into the ROM 4, would be based upon the operating characteristics of a range of motors.

The monitoring device of the present invention may be permanently mounted in-situ within a motor. Alternatively, it may take the form of a hand held device which can be fitted to a particular motor to allow it to be monitored over a period of time and an assessment of its suitability for the particular application at hand determined.

The monitoring device of the present invention may find a wide range of specific applications. For example, in fork lift trucks, vehicles having electric starter motors, precinct cleaners, indeed in almost any machine which makes use of an electric motor.

Finally, the monitoring device in accordance with the present invention has particular application with motors which

make use of pulse width modulation (PWM) to control the output.

The monitoring device may be used to provide a control signal to the PWM generator proportional to the temperature of the motor. Thus, as the temperature of the motor rises above a

5 safe level the monitoring device may vary the output of the PWM generator to regulat the output of the motor and bring it back within safe operating limits.

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CLAIMS

1. A method of monitoring the operating capacity  
of an electric motor, wherein the temperature of a motor is  
sensed, the percentage value of the absolute maximum operating  
temperature of the motor represented by the sensed temperature  
5 is determined and the percentage value is indicated.

2. A method according to Claim 1, wherein the  
percentage value of the absolute maximum operating temperature  
of the motor is determined by interpolating predetermined  
operational data relating to the operating characteristics of  
10 the motor, with the sensed temperature.

3. A method according to Claim 1 or 2, wherein  
the motor cuts-out if its operating temperature exceeds a  
predetermined maximum permitted operating temperature and is  
prevented from operating again until the temperature drops back  
15 below this level or a motor cut-out override is activated by  
the operator.

4. A method according to Claim 3, wherein the motor  
cut-out override cannot be overridden if the operating  
temperature of the motor exceeds a predetermined absolute  
20 maximum operating temperature of the motor, ie 100% of the  
operating temperature range.

5. A method according to any preceeding Claim, wherein  
data relating to the operating conditions of the motor during  
its working life are recorded or stored in a memory.

25 6. A method according to Claim 6, wherein the data  
comprises any combination of the following parameters:-

- a) the total running time of the motor;
- b) the total number of operations performed by the motor;
- c) the number of times the motor is operated beyond the maximum permitted operating temperature;
- d) the number of times the motor is shut-down as a result of reaching the absolute maximum permitted temperature; and,
- e) the operating conditions prevailing during the last operation.

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7. A method according to Claim 6 or 7 wherein data is accessed from the memory means by means of a data link and appropriate memory reading equipment.

8. A monitoring device for an electrical motor comprising temperature sensing means for monitoring the temperature of a motor, memory means containing predetermined operational data relating to the operating characteristics of the motor, control means for correlating the sensed temperature with said predetermined operational data to provide an output representing the sensed temperature as a percentage of the operating temperature range and means for displaying said output.

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9. A monitoring device according to Claim 9, wherein the indicator means comprises a plurality of LEDs each of which represents an incremental increase in the percentage of the operating temperature range.

10. A monitoring device according to Claim 10, wherein the LEDs are of different colours to represent different

operating stages of the motor.

11. A monitoring device according to Claim 8, 9 or 10, wherein the control means comprises a motor cut-out which interrupts the supply of power to the motor if its operating temperature exceeds a predetermined maximum permitted operating temperature and prevents it from operating again until the  
5 temperature drops back below this level.

12. A monitoring device according to Claim 11, wherein the control means also comprises a manually operated motor cut-out override whereby the supply of power to be to the motor  
10 may be recommenced by an operator.

13. A monitoring device according to Claim 11 or 12, wherein the control means comprises means whereby the motor cut-out override may be automatically overridden should the operating temperature of the motor exceed a predetermined  
15 absolute maximum operating temperature of the motor, ie 100% of the operating temperature range.

14. A monitoring device according to any of Claims 8 to 13, wherein the monitoring device comprises additional memory means for storing data relating to the operating conditions of  
20 the motor during its working life.

15. A monitoring device according to Claim 14, wherein the information stored in the additional memory means can be accessed by means of a data link.

16. A monitoring device according to Claim 15, wherein  
25 the data link comprises an infra red transmitter and an infra red sensor.

17. A method of monitoring the operating capacity

of an electric motor substantially as hereinbefore described  
with reference to the accompanying drawing.

18. A monitoring device for an electrical motor  
substantially as hereinbefore described with reference to the  
5 accompanying drawing.

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